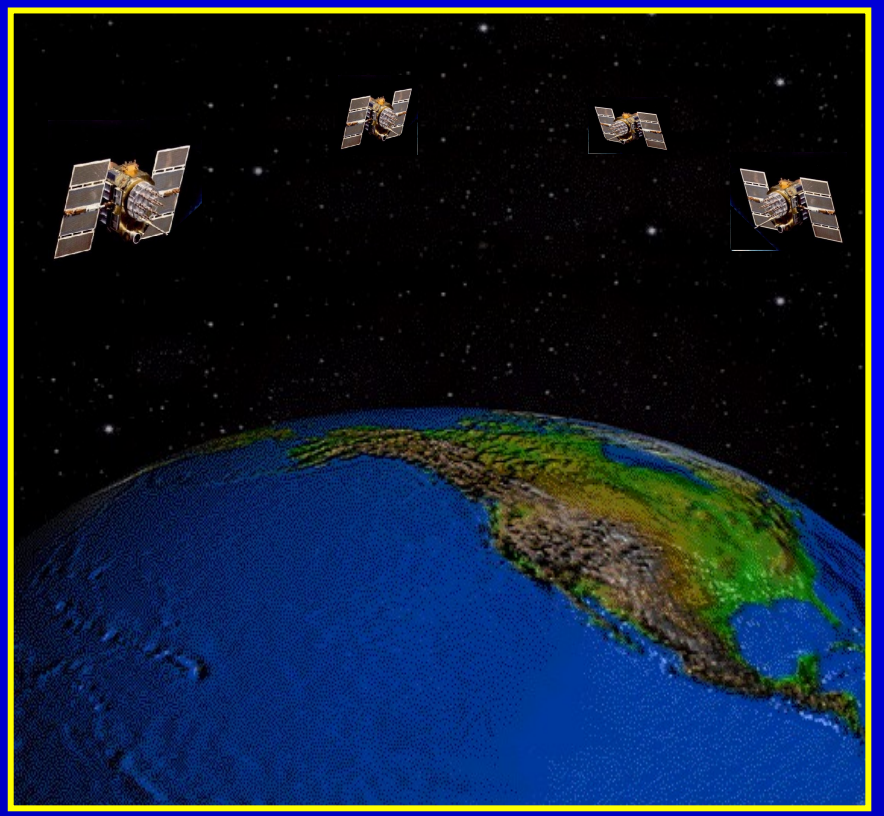
Global Positioning System
Introduction and Military Use

Business of Space **Space Operations Scho**
5 Dec 2001

Overview

- Missions
- System Overview
- Limitations
- Enhancements
- Modernization
- Tactical GPS
- Summary



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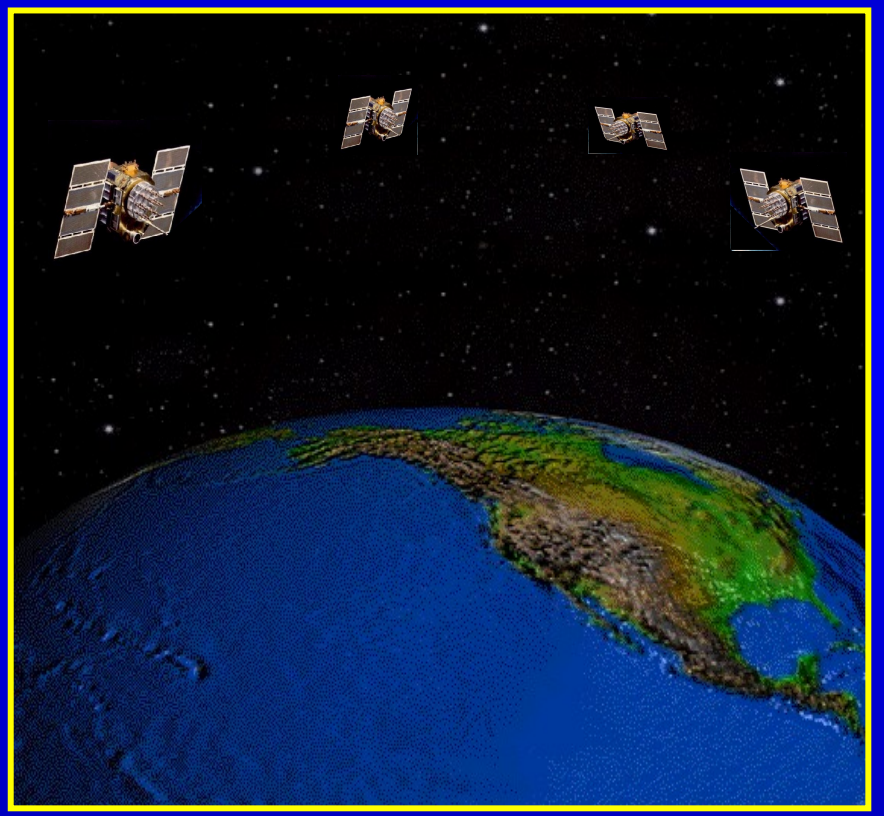
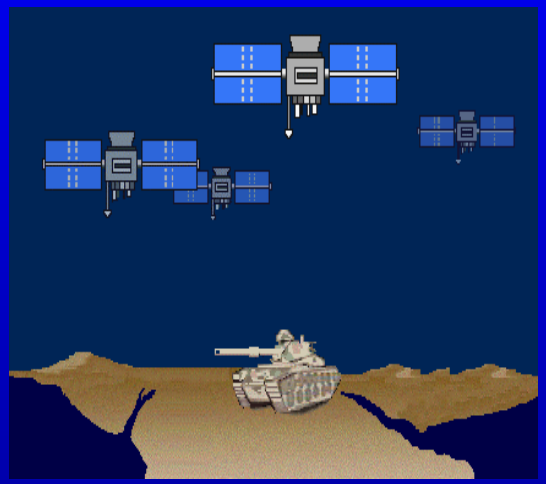


GPS Missions

Mission 1:

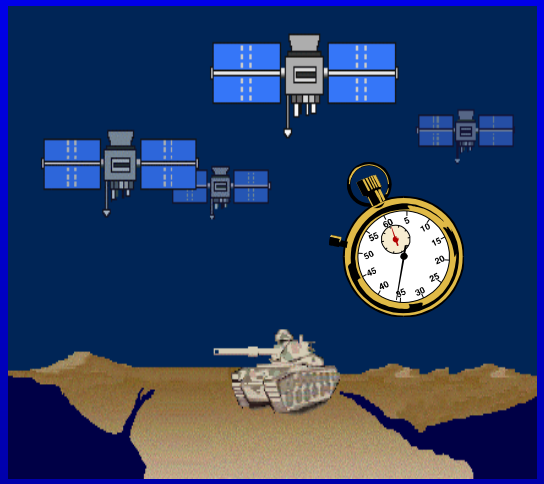
Provides Highly Precise Position and Velocity to Users

- **Worldwide**
- **Any weather**
- **24 hours/day**



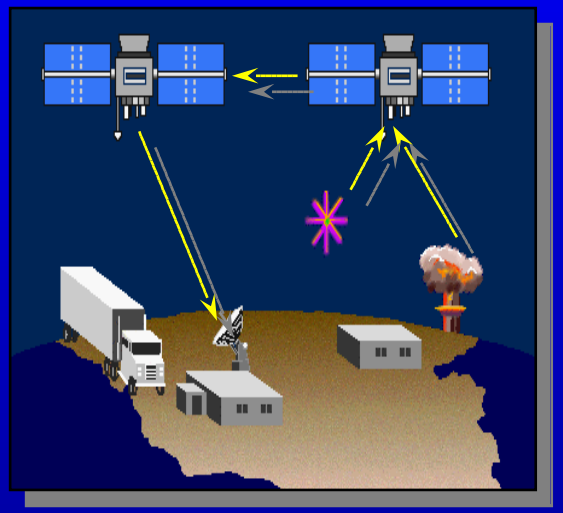
Mission 2:

Provides highly accurate time information for system synchronization
- HQ II,
- COMSATs



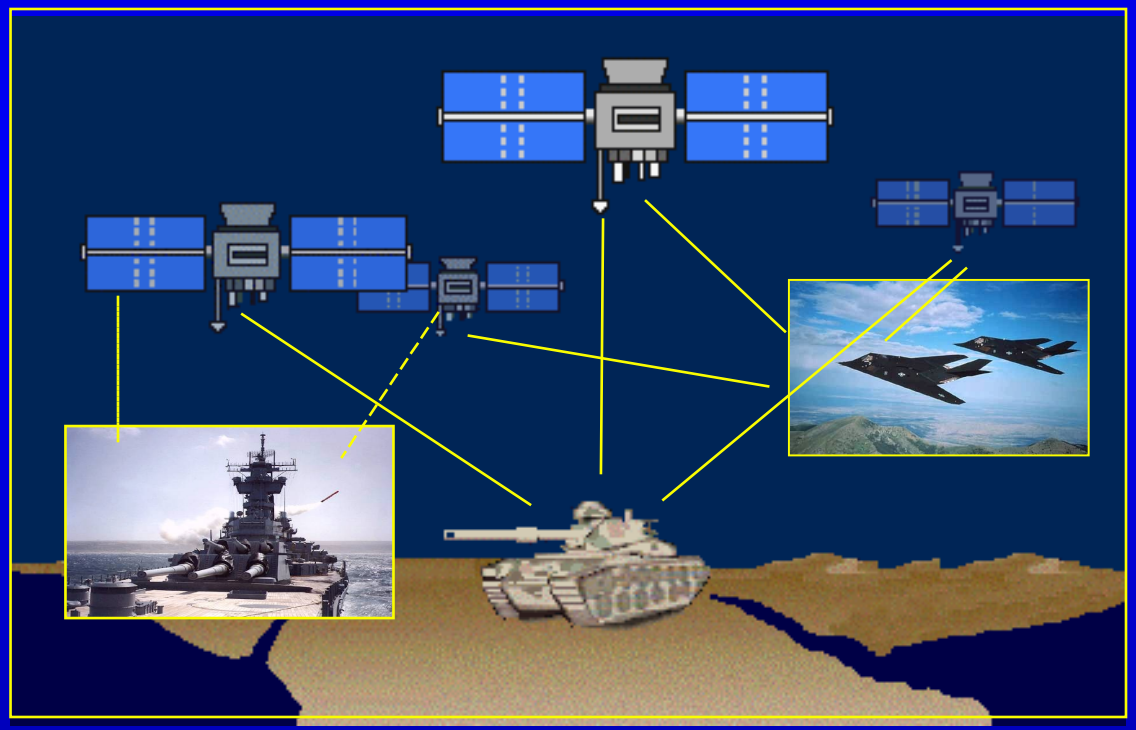
Mission 3:

Provides survivable, worldwide Nuclear Detonation Detection (NUDET) surveillance throughout the entire spectrum of conflict



GPS: Primary Mission

Provides Highly Precise Position, Velocity and Time to Users:



GPS Satellites and Users

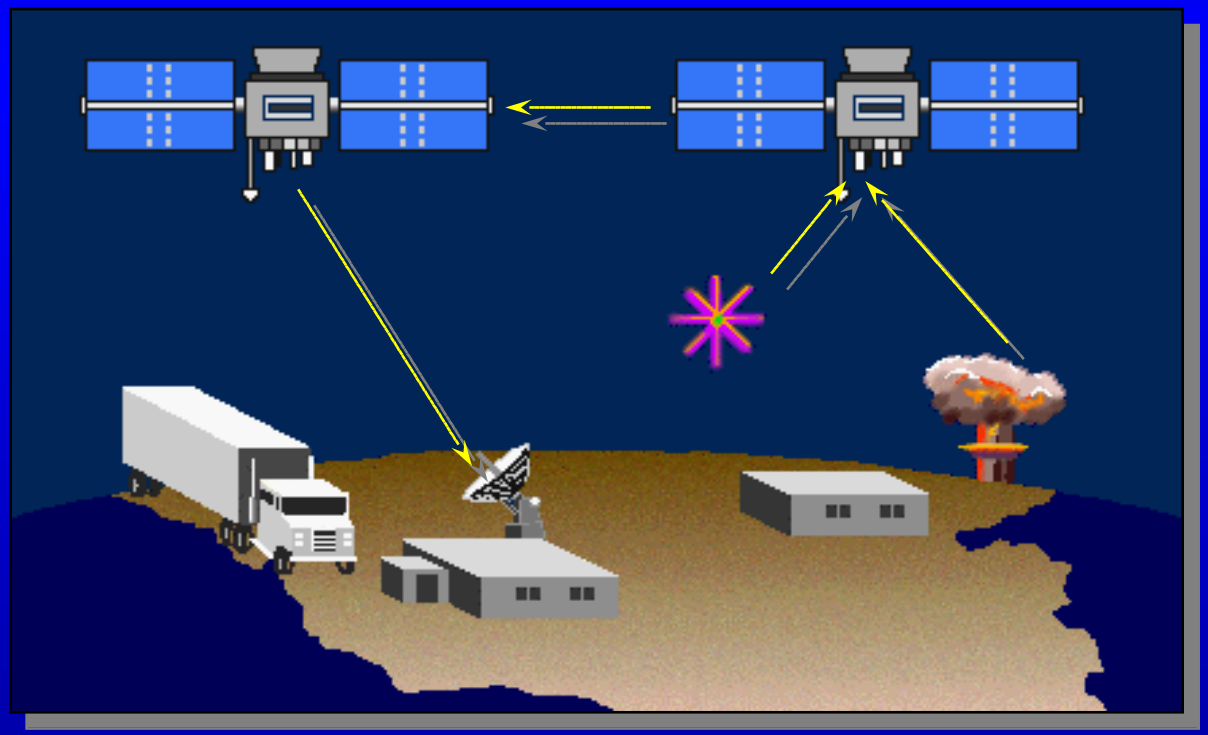
- Worldwide
- Any weather
- 24 hours/day

Time Transfer Mission

- UTC (USNO) Time - DOD time standard
- GPS - The primary time distribution system for DOD
- UTC (GPS) Time - Must be within 1 ms of UTC (USNO)
  - Transmitted correction must be within 28 ns
  - Historically GPS has been within 100 ns and 20 ns respectfully
- Military receiver specification is to determine time within 200 ns (± 1σ)
- Time Transfer uses:
  - Synchronize digital communications
    - HAVE QUICK
    - SINCGARS
    - MILSTAR
    - Commercial systems
  - Synchronize networks

Nuclear Detonation Detection

Provides survivable, worldwide Nuclear Detonation Detection (NUDET) surveillance throughout the entire spectrum of conflict



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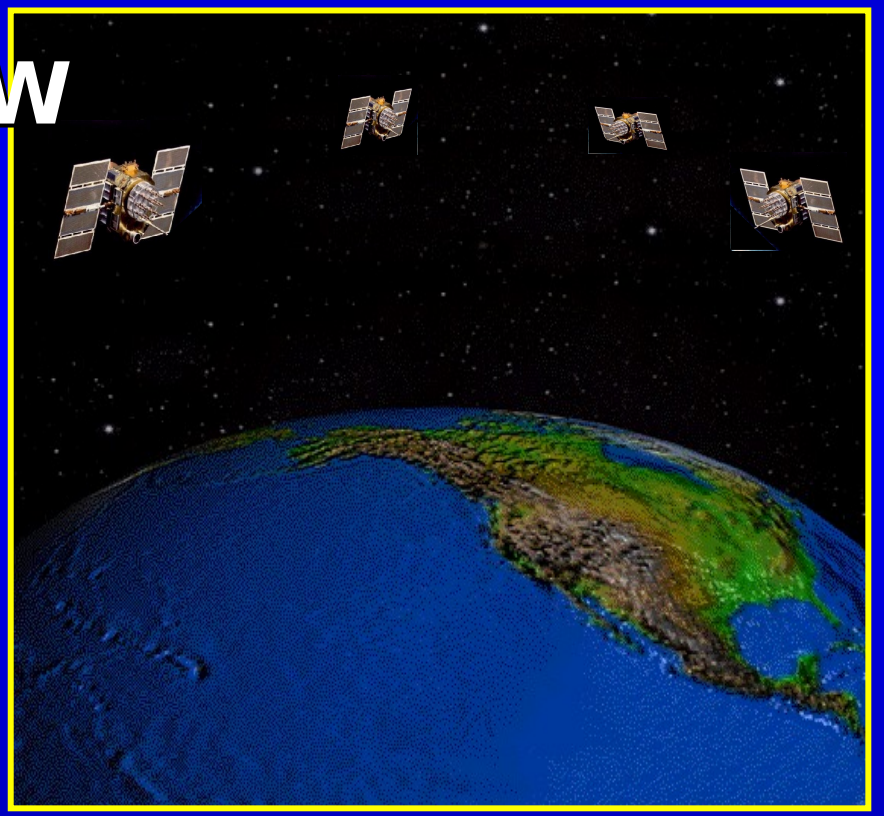


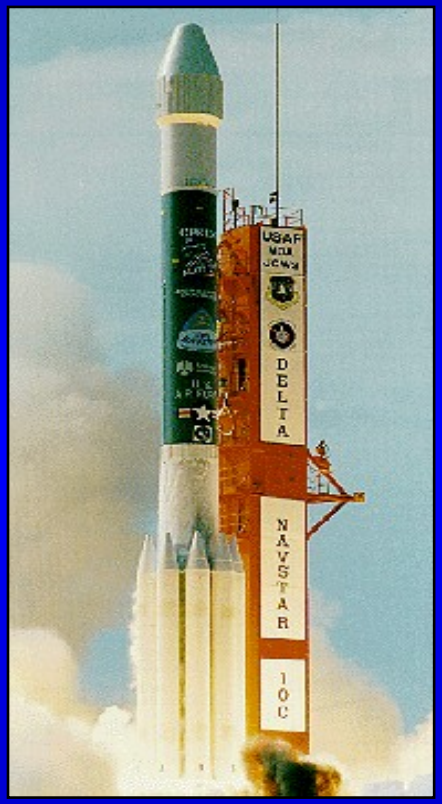
GPS Segments

Space Segment

Control Segment

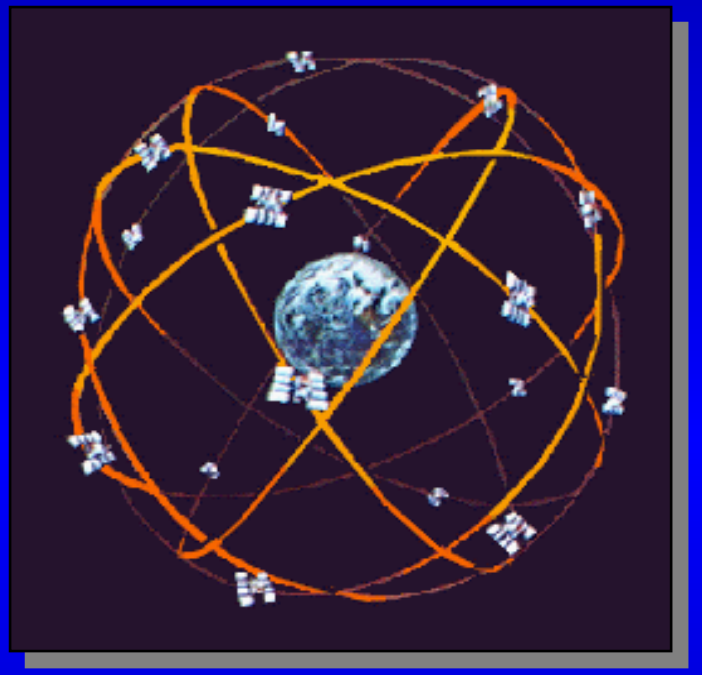
User Segment

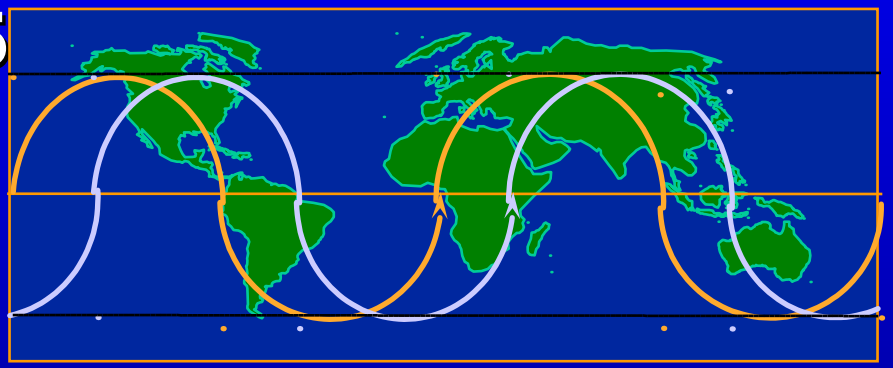
GPS Space Segment



Delta II

- 24 Satellites
- 6 Orbital Planes
- 12 Hour Period
- 10,900 NM
- Inclined 5





GROUND TRACE

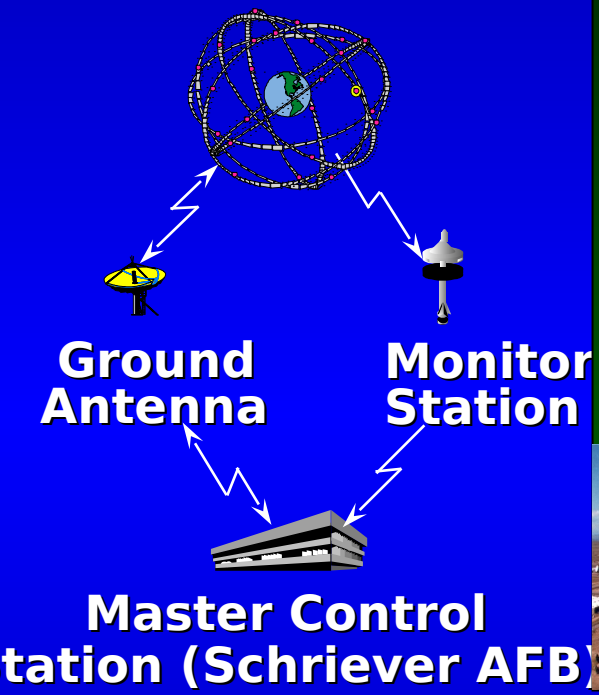
Constellation Status

- **Currently**
  - **28 Satellites on-orbit**
    - **Latest launch (IIR) - 30 Jan 01**
- **Block IIR**
  - **Two to launch w/o mod**

Constellation Modernization

- 12 Block IIR
  - 2nd civ freq and Lm
  - Launch ~2003 - 2006
- 12 Block IIF
  - Above plus 3rd civ freq
  - First launch ~2006
- GPS III
  - ~2008-2030

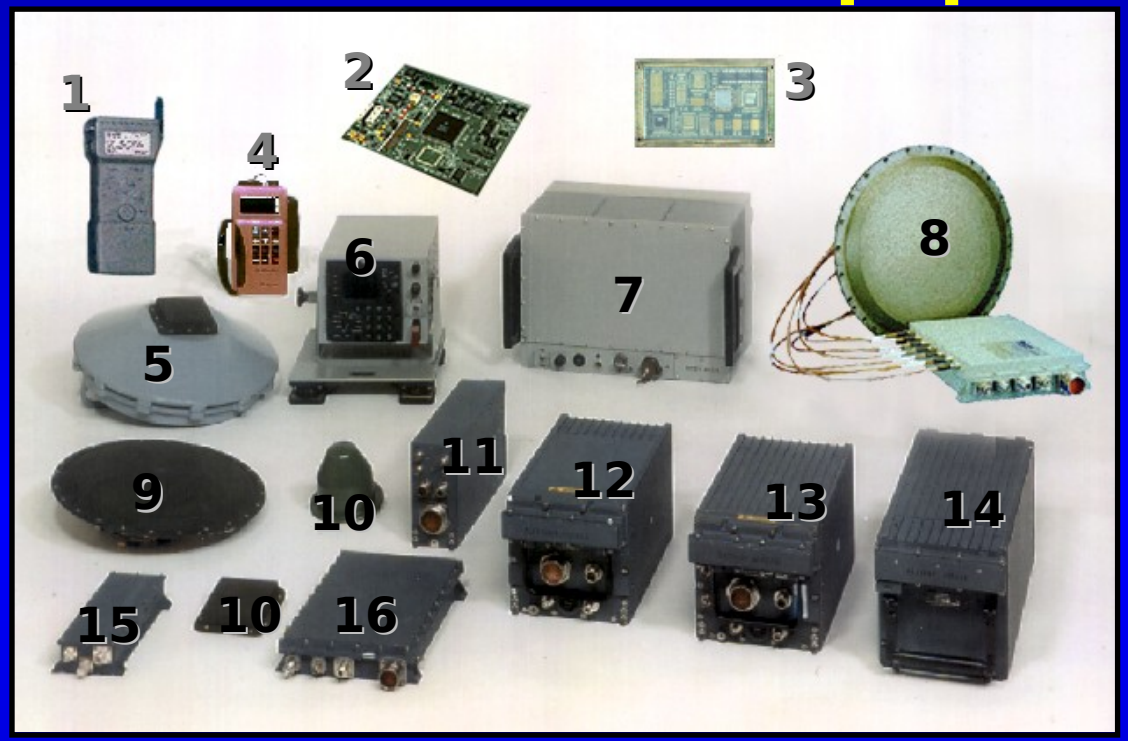
GPS Ground Segment
GPS Operational Control System (OCS)

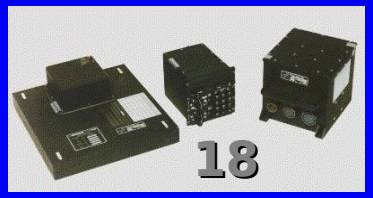


- ***Master Control Station (MCS):*** **Satellite control, System operations**
- ***Alternate Master Control Station:*** **Training, Back-up (2005)**
- ***Monitor Station (MS):*** **L-band; Collect range data, Monitor navigation signal**
- ***Ground Antenna (GA):*** **S-band; Transmit data/commands, Collect telemetry**

GPS User Segment

GPS User Equipment (UE)



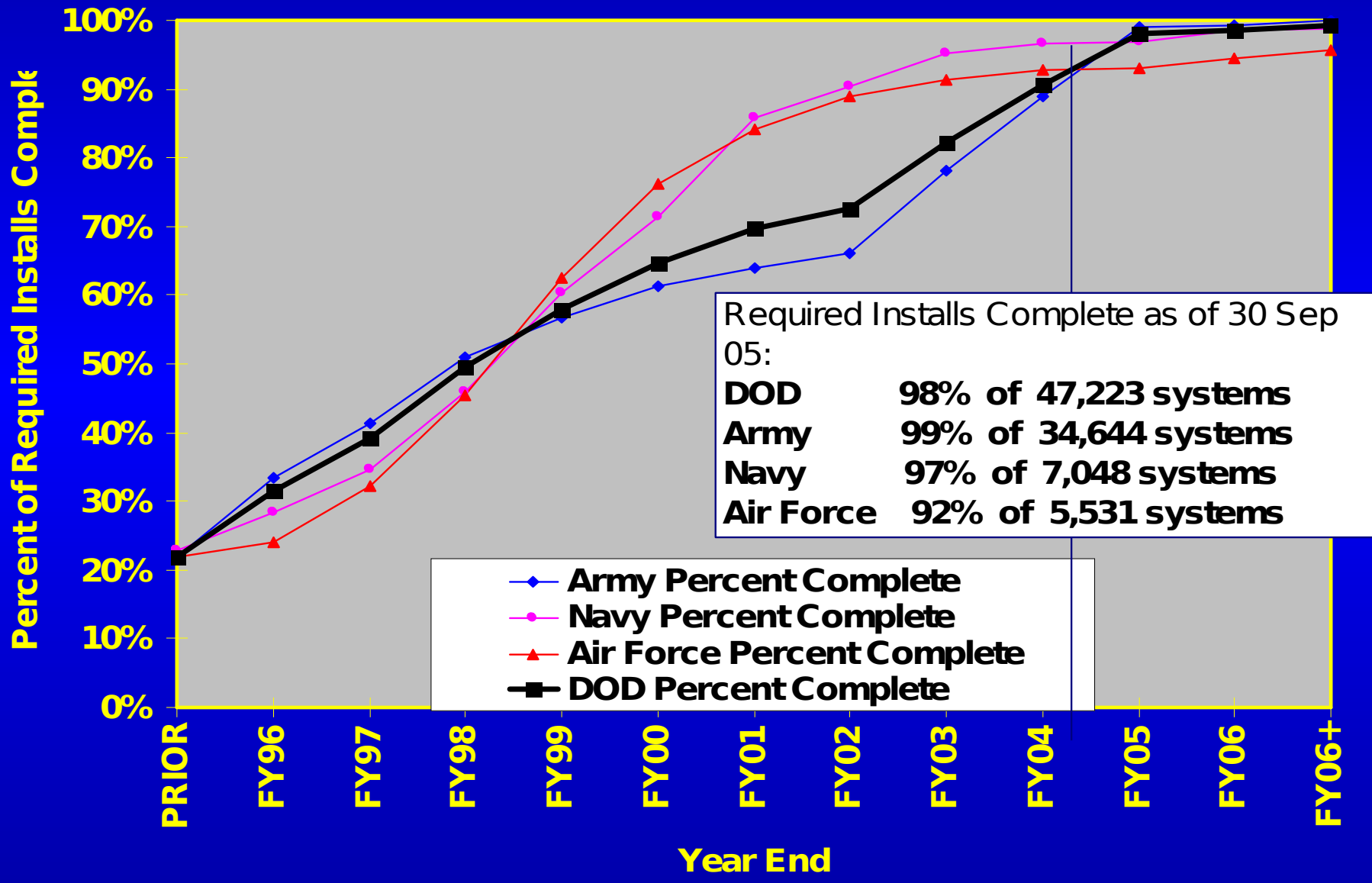


1. Combat Survivor/Evader Locator (CSEL)
2. GPS Receiver Applications Module (GRAM) with SAASM
3. Selective Availability Anti-Spoofing Module (SAASM)
4. Precision Lightweight GPS Receiver
5. (PLGR)
6. FRPA Ground Plane (FRPA-GP)
7. Standard Control Display Unit (CDU)
8. Receiver 3S
   GPS Antenna System (GAS) -1
9. Controlled Radiation Pattern Antenna
10 (CRPA)
   . Fixed Radiation Pattern Antenna (FRPA
11 Miniature Airborne GPS Receiver (MAGI
   . Receiver OH (MIL-STD-1553)
12 Receiver UH (ARINC 429)
   . Receiver 3A
13 Antenna Electronics AE-4
   . Antenna Electronics AE-1/AE-1A
14 Embedded GPS/INS (EGI)
   1 Doppler-GPS Navigation System (DGNS

Air Force GPS Integration

- **GPS integrated into approximately 84% of aircraft fleet by end FY01**

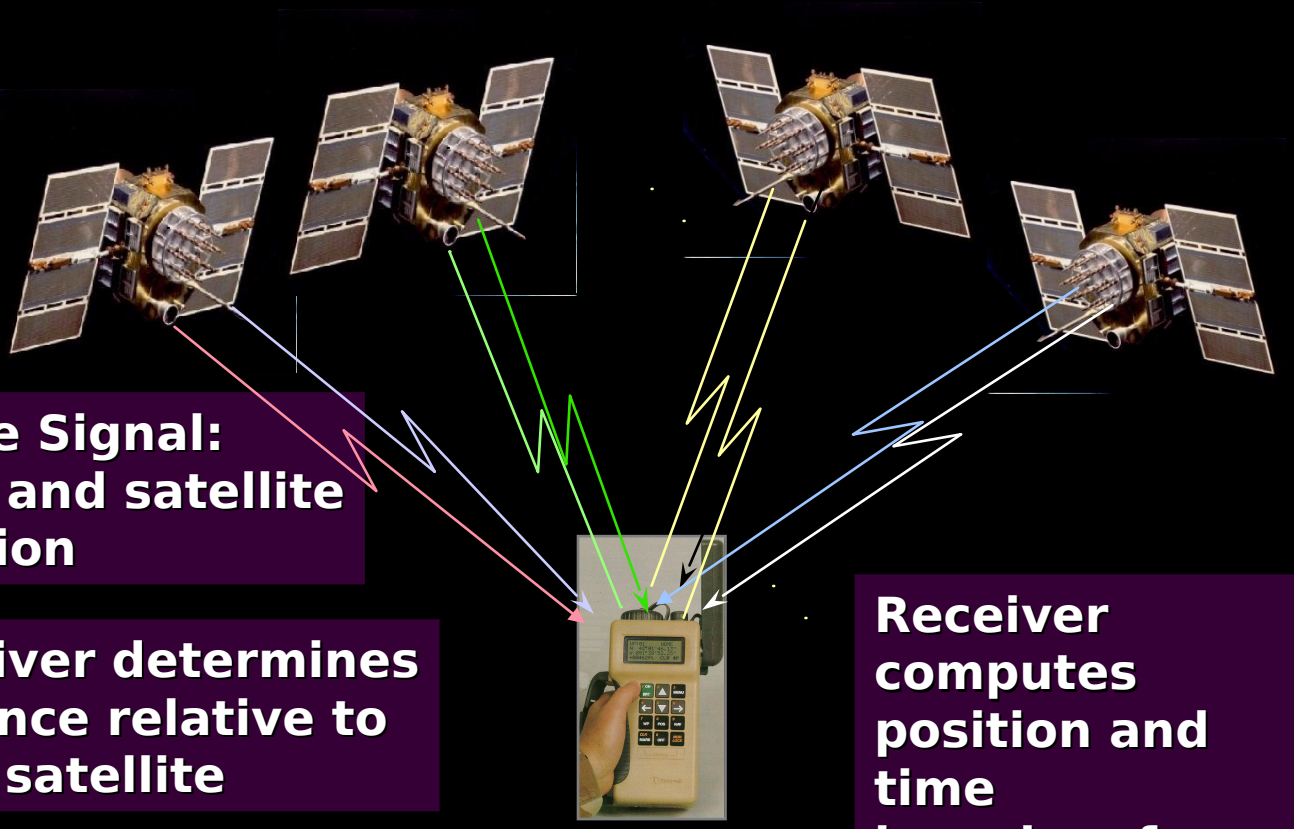
DOD GPS Installations



Required Installs Complete as of 30 Sep 05:

DOD	**98% of 47,223 systems**
Army	**99% of 34,644 systems**
Navy	**97% of 7,048 systems**
Air Force	**92% of 5,531 systems**

How Does GPS Work?



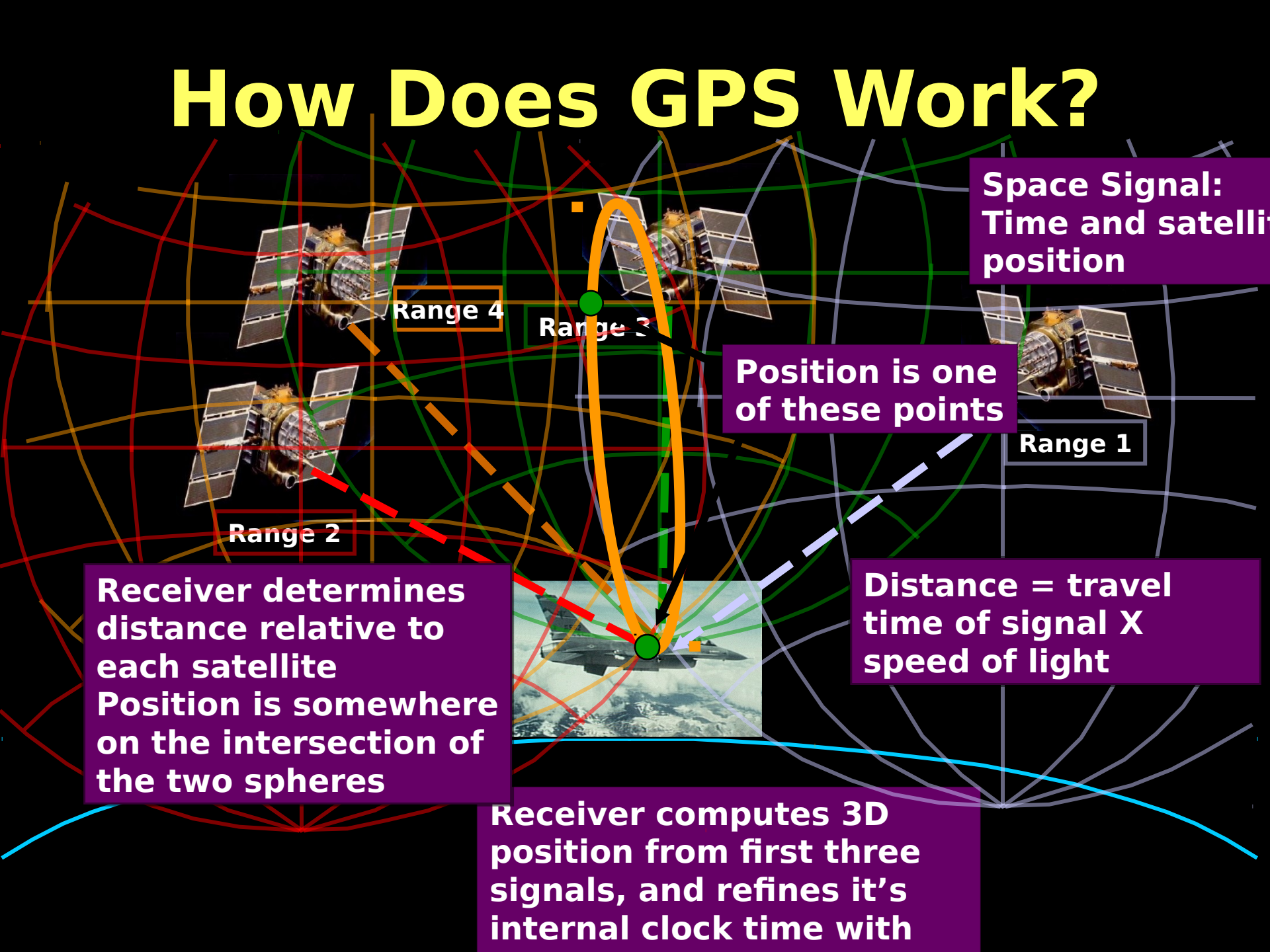
Space Signal:
Time and satellite position

Receiver determines distance relative to each satellite

Receiver computes position and time
based on four

Distance = time of receipt less time of transmission X speed of light

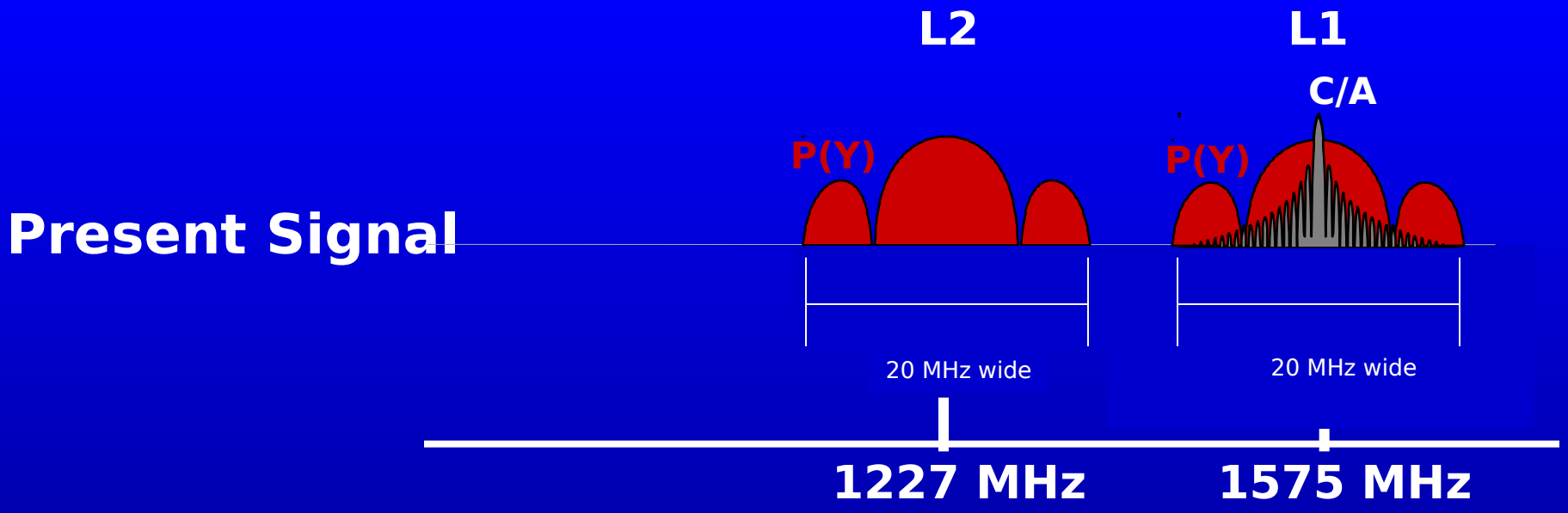
How Does GPS Work?



GPS Signal Specifics

C/A = Course Acquisition Signal (Civilian users)

P(Y) = Encrypted Precision Signal (Authorized users)



Positioning Services

- **Standard Positioning Service (SPS)**
  - **Coarse/Acquisition (C/A) code**
    - **Recreational & commercial receivers**
    - **Military receivers for initial signal acquisition**
- **Precise Positioning Service (PPS)**
  - **Requires P (Y) - code receiver**

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- **LIMITATIONS**
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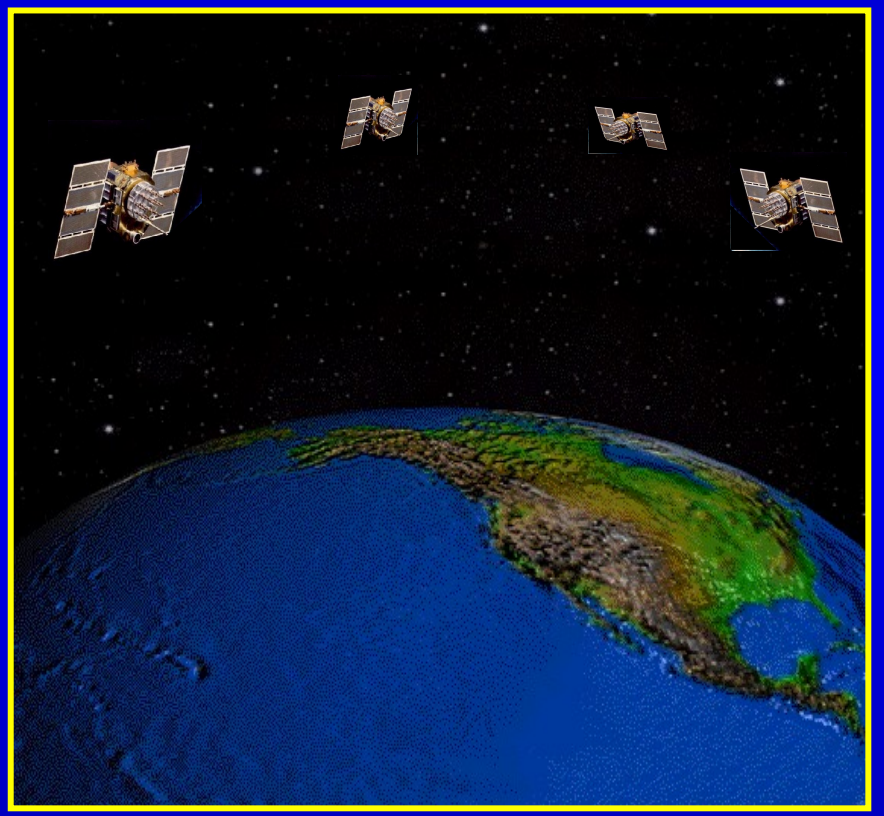


GPS Limitations

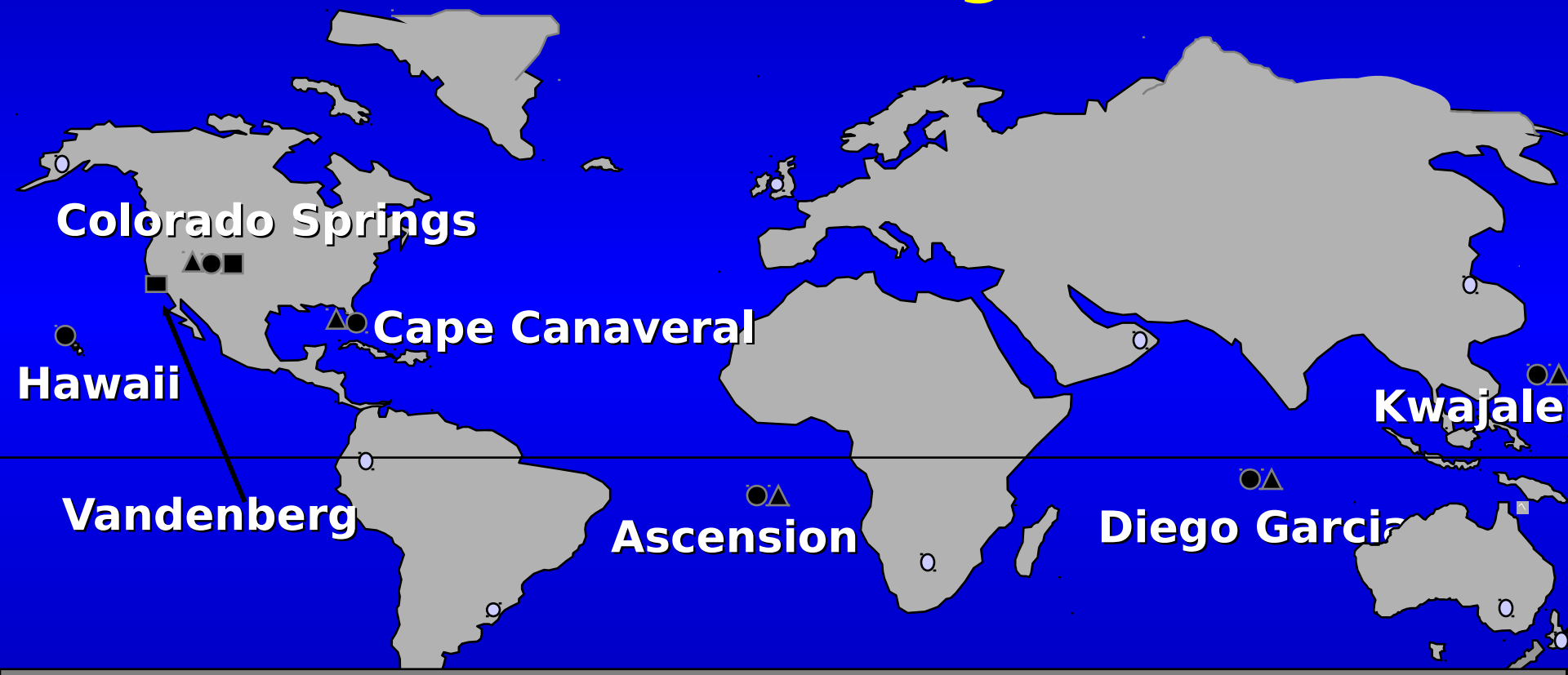
- Dependent on Ground Stations
- Accuracy/Errors
- Dilution of Precision

GPS Limitations

- **DEPENDENT ON GROUND STATIONS**
- **Accuracy/Errors**
- **Dilution of Precision**

GPS Limitations

GPS Control Segment



GPS Limitations

- Dependent on Ground Stations
- **ACCURACY/ERRORS**
- Dilution of Precision

GPS Limitations
Error Sources

1. Satellite Position Error:

Actual Position of Satellite

Perceived Position of Satellite

Actual Position of User

Perceived Position of User

GPS Limitations
Error Sources

2. Satellite Clock Error:

Satellite Clock Slow

1 ns = 1 foot

Satellite Clock Correct

Actual User Position

Satellite Clock Fast

1 ns = 1 foot

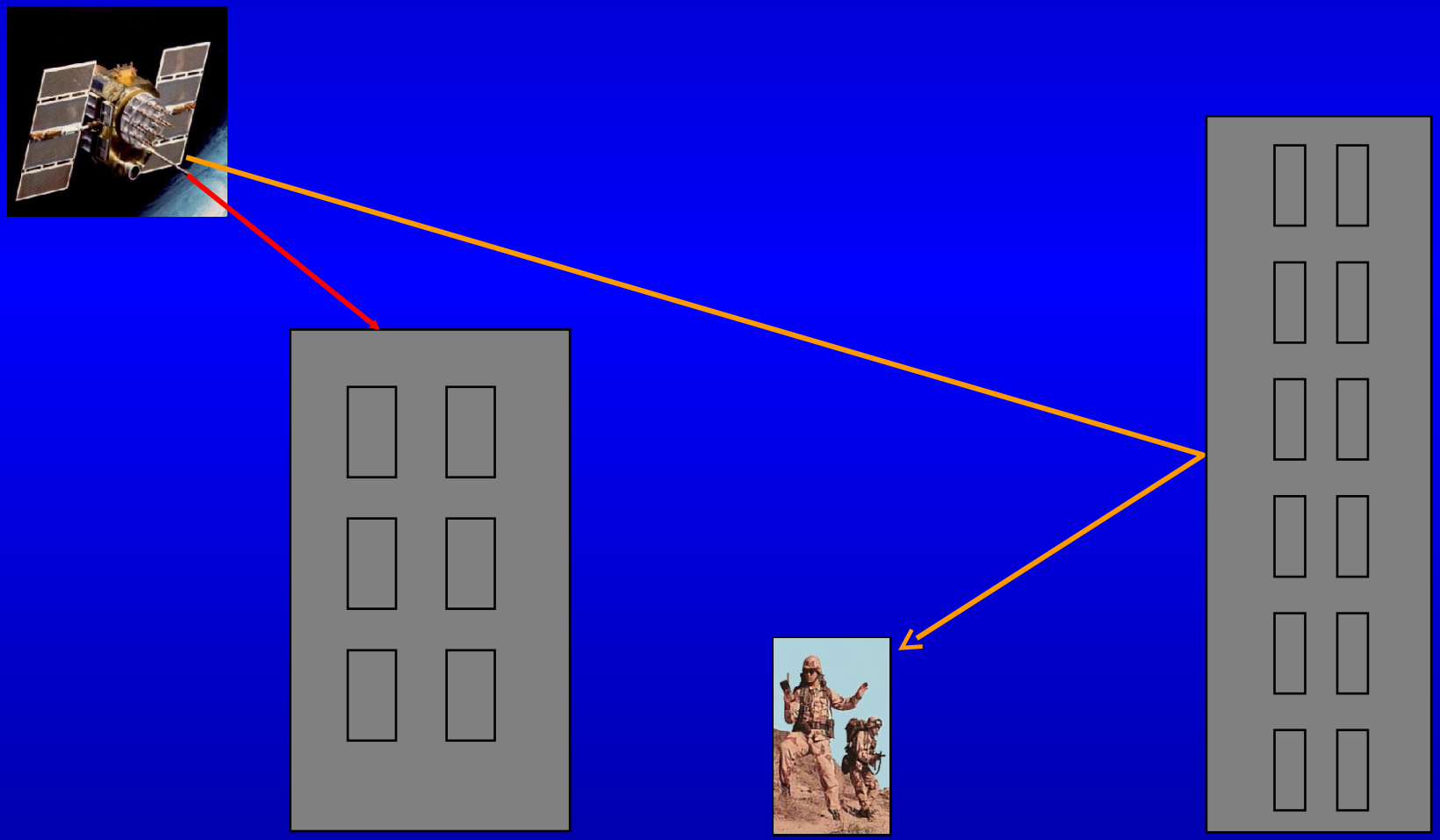
GPS Limitations
Error Sources

3. Equipment/User Errors:

- **Receiver Noise**
- **Wrong Datum Set**
- **Buffoonery**

GPS Limitations
Error Sources

4. Multi-Path:

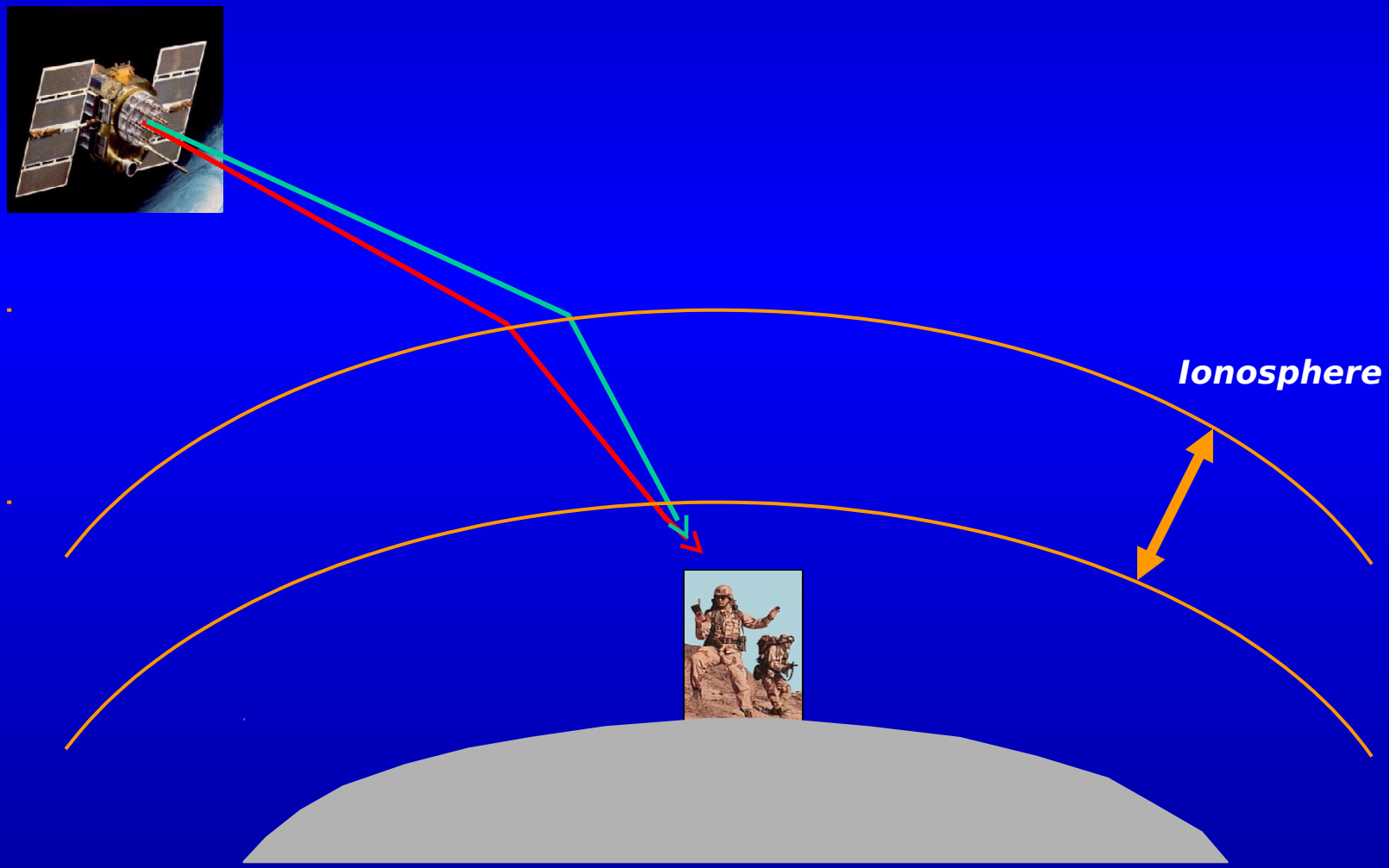


GPS Limitations
Error Sources

5. Troposphere:

GPS Limitations
Error Sources

6. Ionosphere:



GPS Limitations
Error Sources

7. Selective Availability:

- **Intentionally give wrong clock time to decrease accuracy**
- **Turned off - 2 May ‘00**

Summary of Error Sources

(Theoretical per-satellite accuracy in meters)

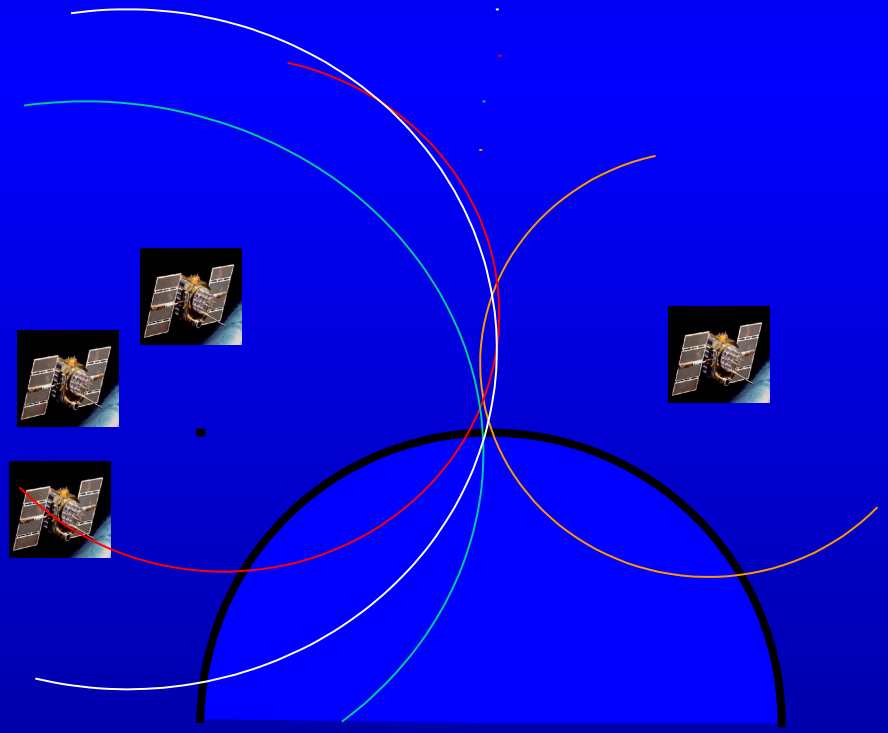
(1 sigma)	PPS	SPS
• Satellite clock	2.1	2.1
• Ephemeris	2.0	2.0
• Ionosphere	0.5	4.0
• Troposphere	0.7	0.7
• Receiver noise	0.5	2.5
• Multipath	0.5	2.5
• Total (root-sum-square)	3.2	6.1

GPS Limitations

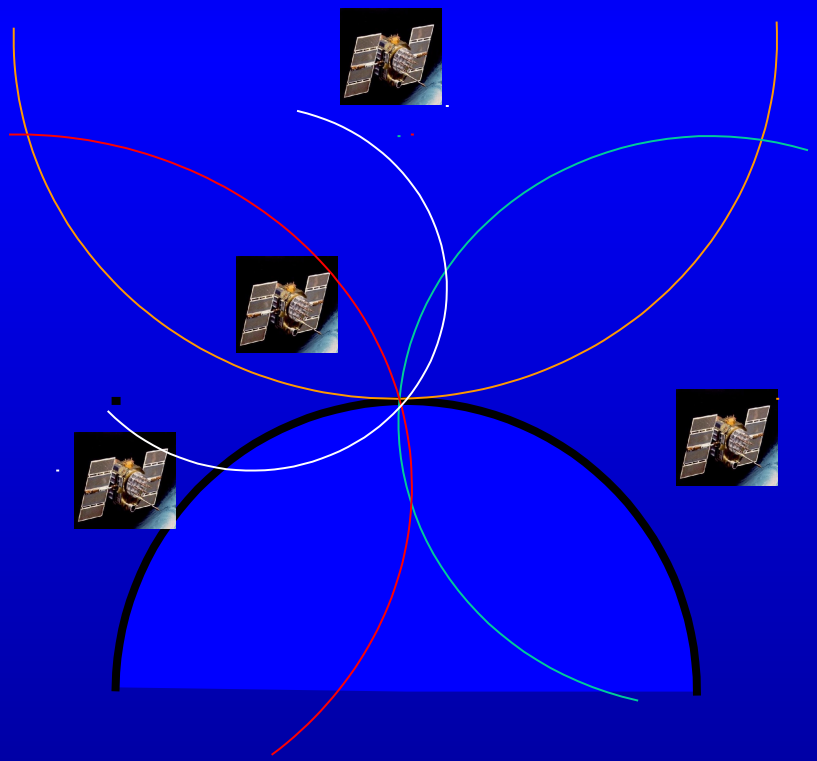
- Dependent on Ground Stations
- Accuracy/Errors
- **DILUTION OF PRECISION**

Dilution of Precision

Poor Geometry:



Good Geometry:

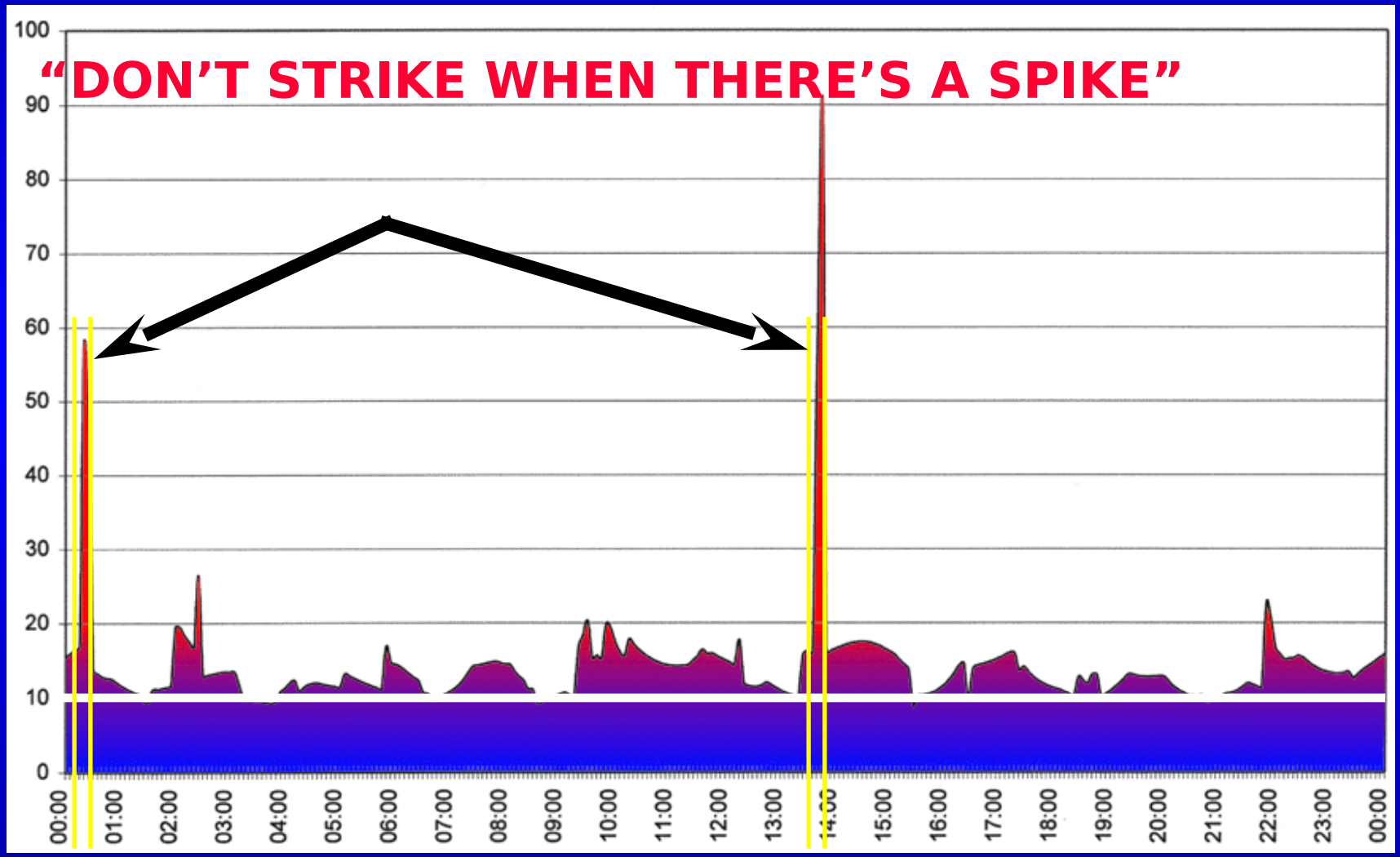


GPS Accuracy Prediction Models

- Operational Model to Exploit GPS Accuracy (OMEGA)
- Space Battle Management Core System (SBMCS)
  - Nav Accuracy Tool

GPS modeling removes some of the guess work

Accuracy/Attack Timing



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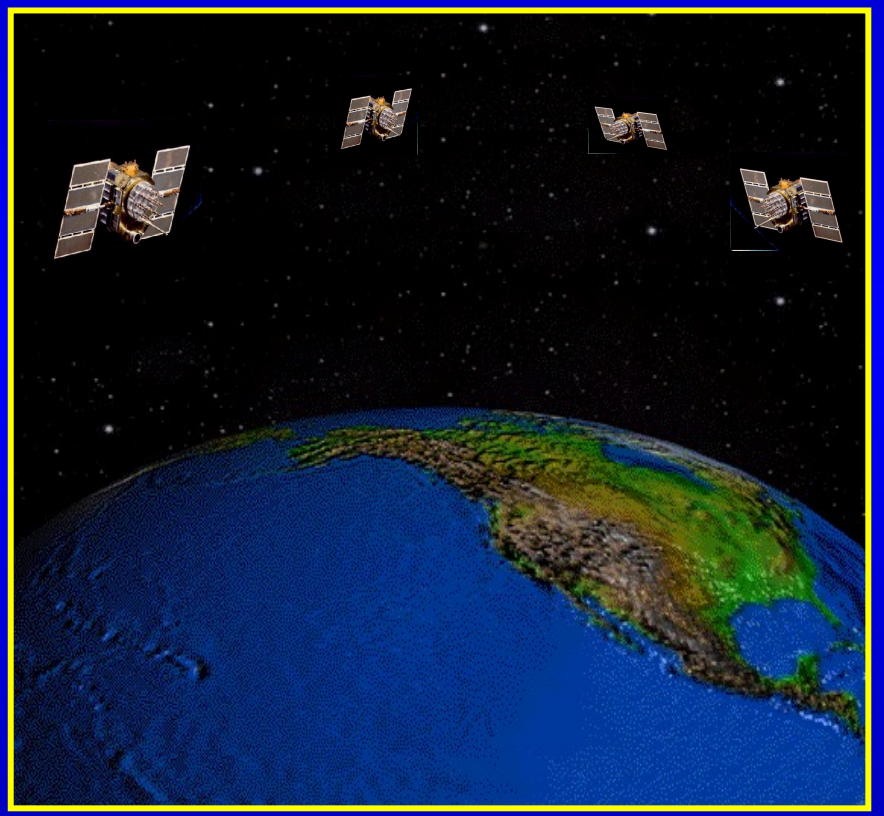

GPS Enhancements

- Differential GPS (DGPS)
- Wide area augmentation system (WAAS)
- Wide area GPS enhancement (WAGE)

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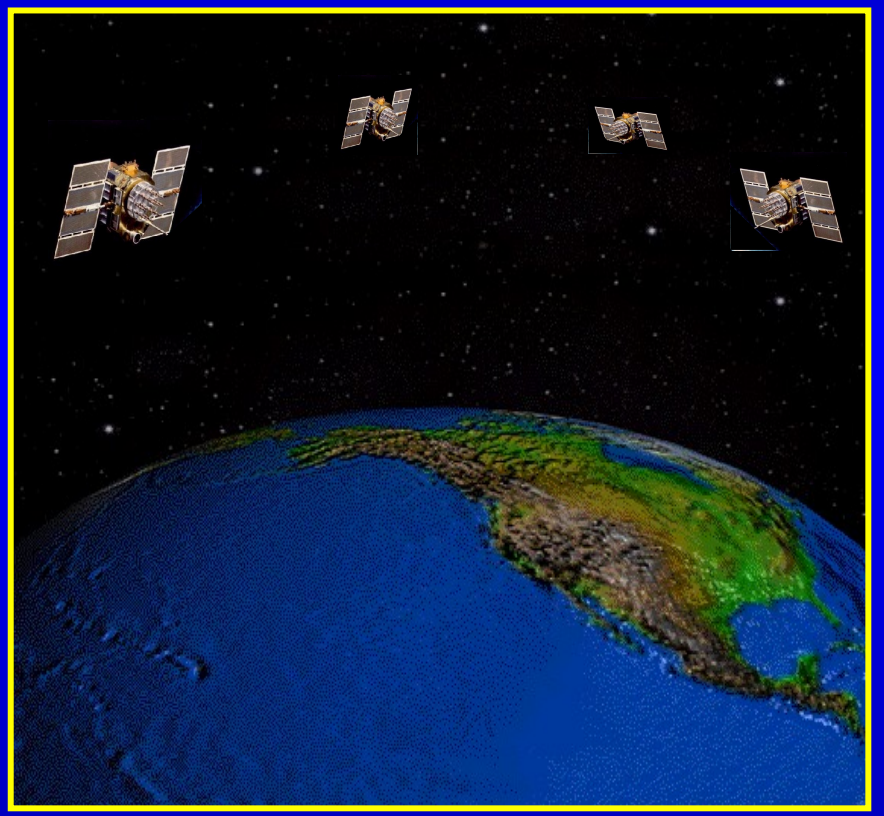
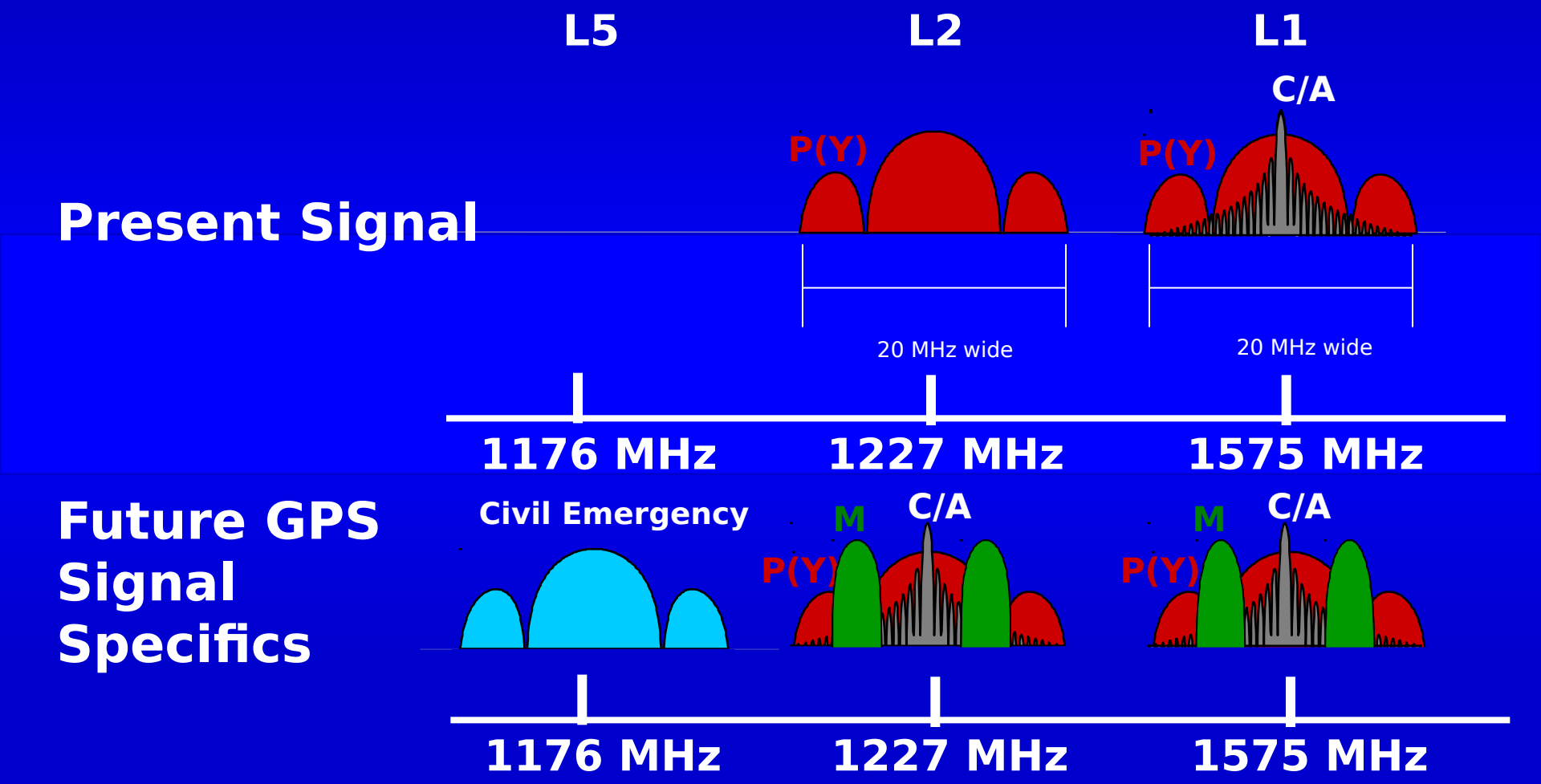


New Signals

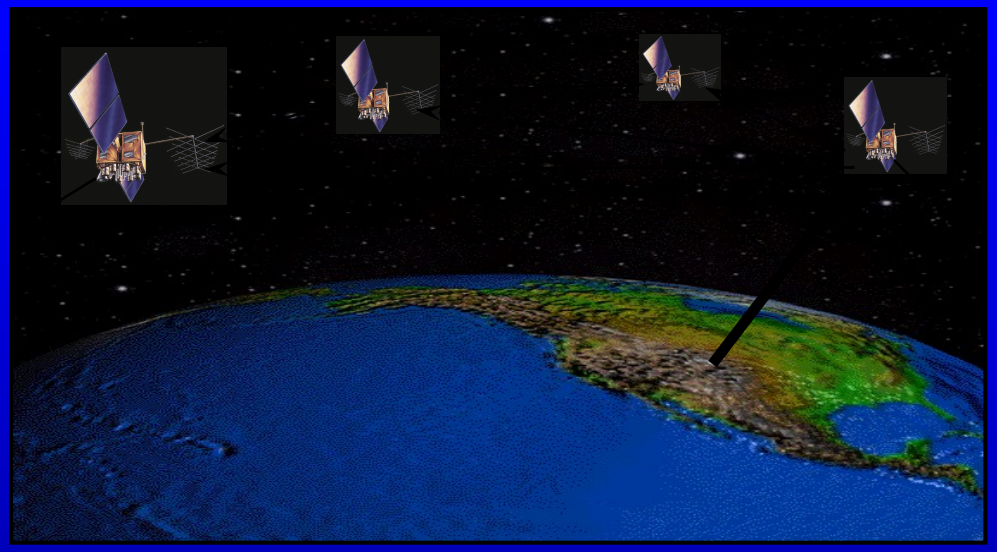

L5
L2
L1
C/A
P(Y)
P(Y)
Present Signal
20 MHz wide
20 MHz wide
1176 MHz
1227 MHz
1575 MHz
Future GPS Signal Specifics
Civil Emergency
M
C/A
P(Y)
M
C/A
P(Y)
1176 MHz
1227 MHz
1575 MHz

AUTO-NAV

- BLOCK IIF/GPS III Satellites only
- Key components are self-ranging and cross-linking
- Requires at least six compatible satellites (2007+)
- Full AUTO-NAV Constellation ~2018
- Allows monthly uploads vice daily uploads to maintain accuracy

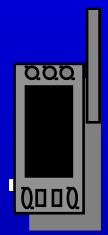
Crosslinks

- **Allows upload via single ground to satellite link - Block IIF and beyond**



Hand-held Receiver Modernization

PLGR:		DAGR:
• Single (L1 only)	*Frequency*	• Dual (L1/L2)
• PPS-SM	*Security*	• SAASM
• Text only	*Display*	• Graphical
• 5 Maximum	*Satellites*	• All-in-View
• 24 dB	*Anti-Jam*	• 34 - 42 dB
• 6 minutes	*TTFF*	• 1 minute
• 2.75 lbs	*Weight*	• ≤ 1.9 lbs
• ≤ 120 cu. in.	*Volume*	• ≤ 38 cu. in.



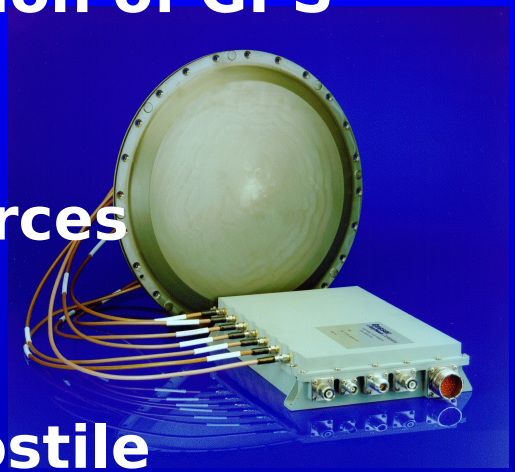
PPS-SM = Precise Positioning Service - Security Module
TTFF = Time to First Fix

Airborne Receiver Modernization (MAGR 2000 Program)

- First JPO common User Equipment (UE) based on new open systems architecture
  - Card vs Box replacement
  - Backward and forward compatibilit
    - allows integration of future NAV improvements
    - Increased capability over MAGR
      - Receiver Autonomous Integrity Monitoring (RAIM)
      - Fault Detection and Exclusion
      - All In View - increased jam resistance

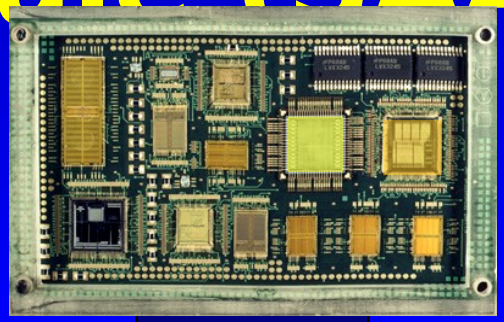
GPS Antenna System - 1 (GAS-1)

- Controlled Reception Pattern Antenna (CRPA)
  - Receives GPS RF Signals (L1/L2); sends signals to AE
- Antenna Electronics (AE)
  - Forms antenna "Nulls" (decreased energy input) in direction of GPS interference sources (jammers or unintentional)
  - Handles multiple interference sources
  - Conditions RF signals and outputs to receiver
- Meet user's needs to operate in a hostile electronic environment (Anti-Jam)



Selective Availability/Anti-Spoof Module (SAASM)

SAASM implements multi-layered security



Functional

- Black keys: unclassified
- Electronic keys

Physical

- Built-in protection
- Tamper-resistant coating

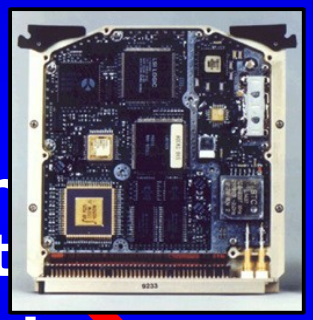
Procedural

Single US Government facility authorized to load operational Key Data Processor (KDP) software

"SAASM represents the next generation of GPS security devices mandated for use in all military receivers procured after 1 October 2002. SAASM provides the highest level of GPS navigation accuracy, integrity, and protection to the US military and its authorized allies."

GPS Receiver Applications Module (GRAM)

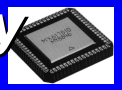
- GRAM is a “GPS JPO approved PPS receiver on a card”
- Allows customers to embed a standar approved GPS engine into a host syst
- Six different form factors determined by the marketplace
- Basis for receiver Open Systems Architecture



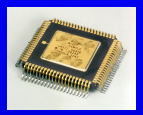
GRAM-SAASM Evolution For GPS User Equipment

Yesterday

Precise Positioning Service-Security Module (PPS-SM)

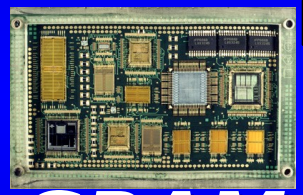


Auxiliary Output Chip (AOC)



Today

SAASM



GRAM

Tomorrow

GRAM-SAASM

GRAM-SAASM
Key to an open systems architecture

Enables forward compatibility for NAVWAR/modernization modifications

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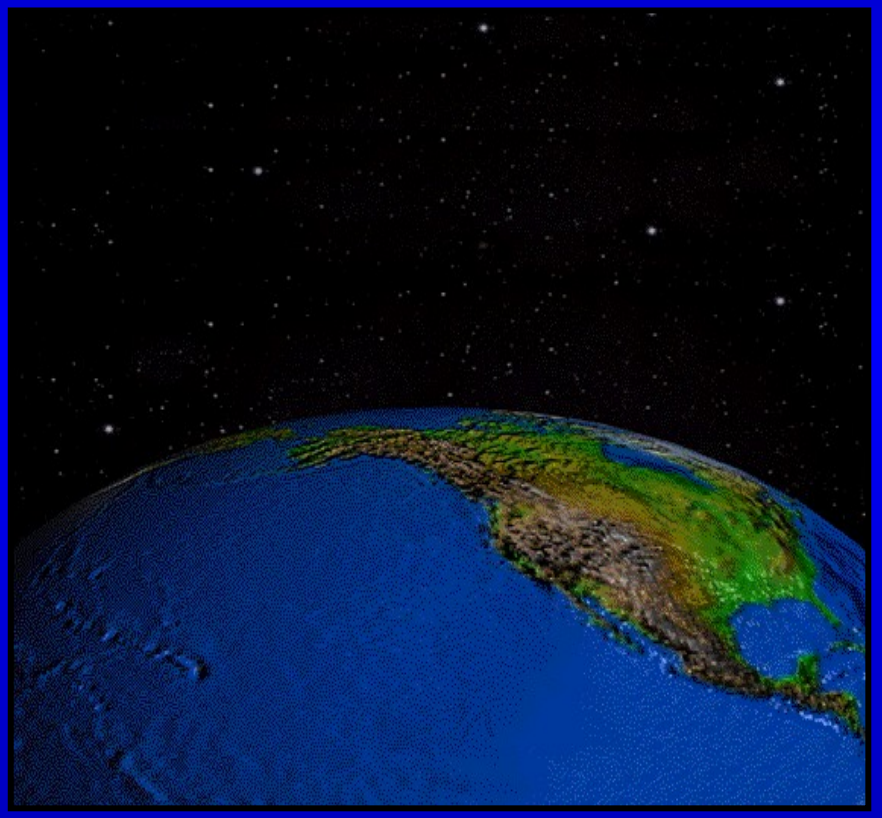
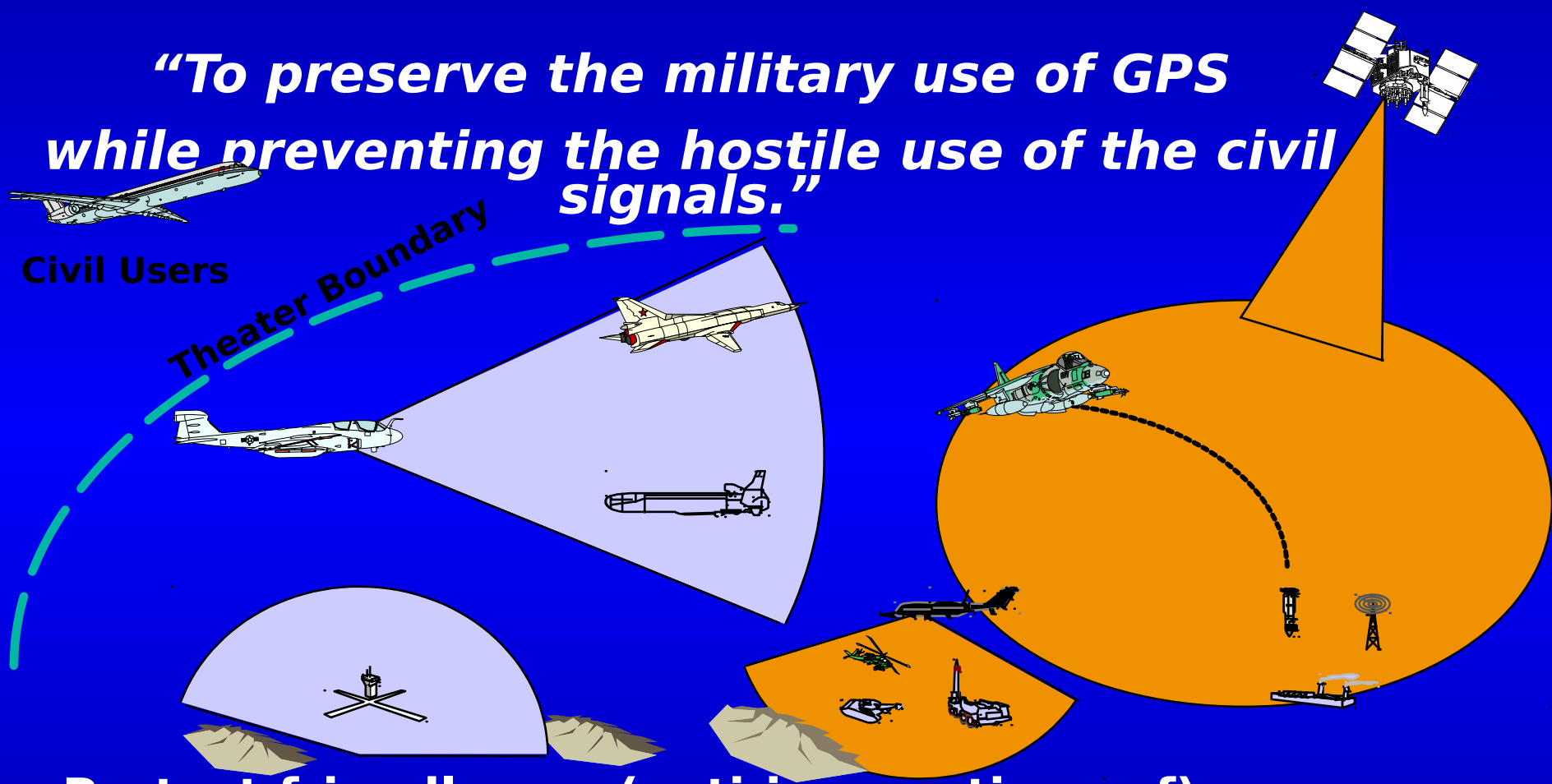
- **TACTICAL GPS**
- Summary



NAVWAR

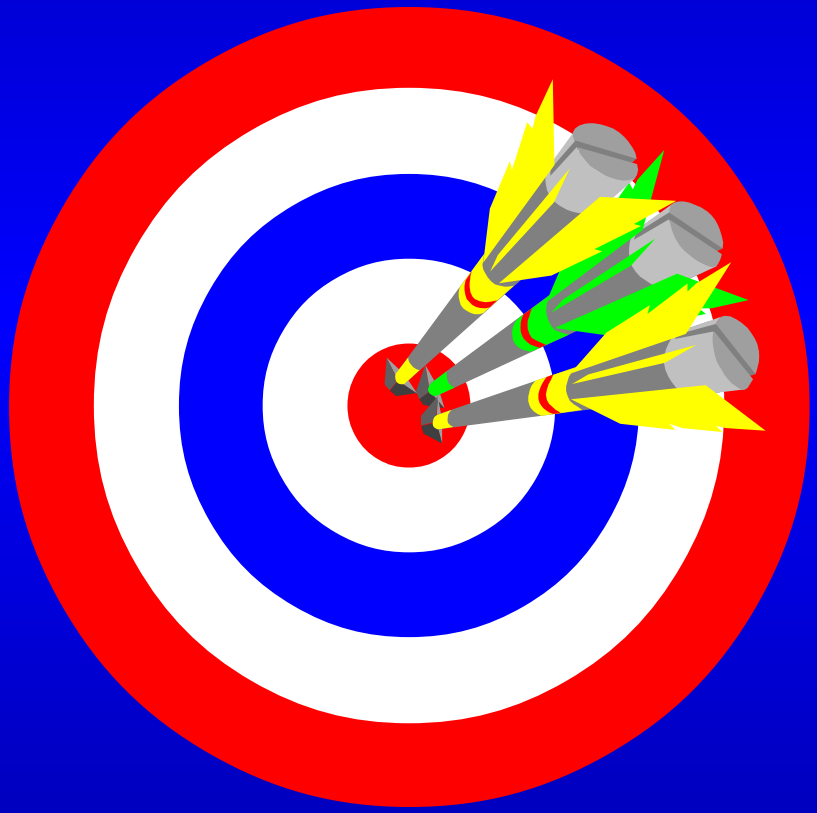
"To preserve the military use of GPS while preventing the hostile use of the civil signals."



- **<u>Protect</u> friendly use (anti-jam, anti-spoof)**
- **<u>Prevent</u> adversary use (jamming, S/A)**
- **<u>Preserve</u> civil use outside the theater (precision EW)**

GPS Aided Munitions

- ATACMS
- Tomahawk (RGM/UGM 109)
- HARM
- AGM 130
- Conventional Air Launched Cruise Missile (CALCM)
- Joint Direct Attack Munition (JDAM)
- Joint Standoff Weapon (JSOW)
- Joint Air-to-Surface Stand-Off Missile (JASSM)



AGM-130

- IR or Optically Guided Rocket assisted Glide bomb
- Semi-hard target capability
- GPS navigation until 2-3 miles from target
- 3,000 lb class

Uses:

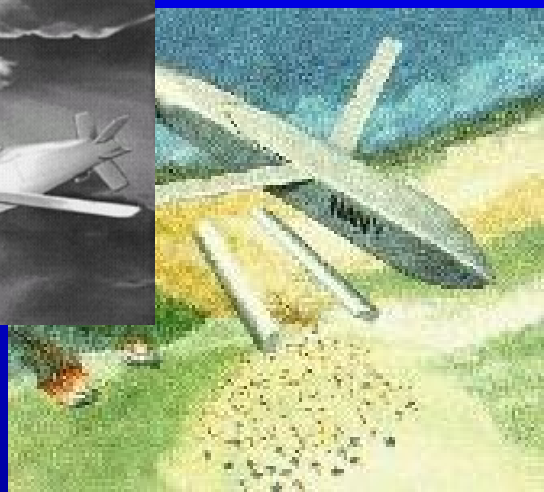
- Precise Positioning Signal
- Dual Frequency
- Back-up Nav: INS, “Man-in-t loop” terminal guidance

HARM (AGM-88 D)

- High-Speed Anti-Radiation Missile
- Block V incorporates a capability vs. high-power GPS jammers
- Block VI incorporates GPS package with INS back-up
  - GPS coordinates used to define NOTACK areas
  - Retrofit begins in 2003

Joint Stand Off Weapon (JSOW)

- GPS/INS guided glide bomb
  - 1000 lb class
  - Range 15-40 NM
- Three warhead variants (3 meter CEP)
- 2002 version with terminal seeker
- Dual Frequency
- Jam Resistant Antenna



Combat Search and Rescue

HOOK-112 **CSEL**

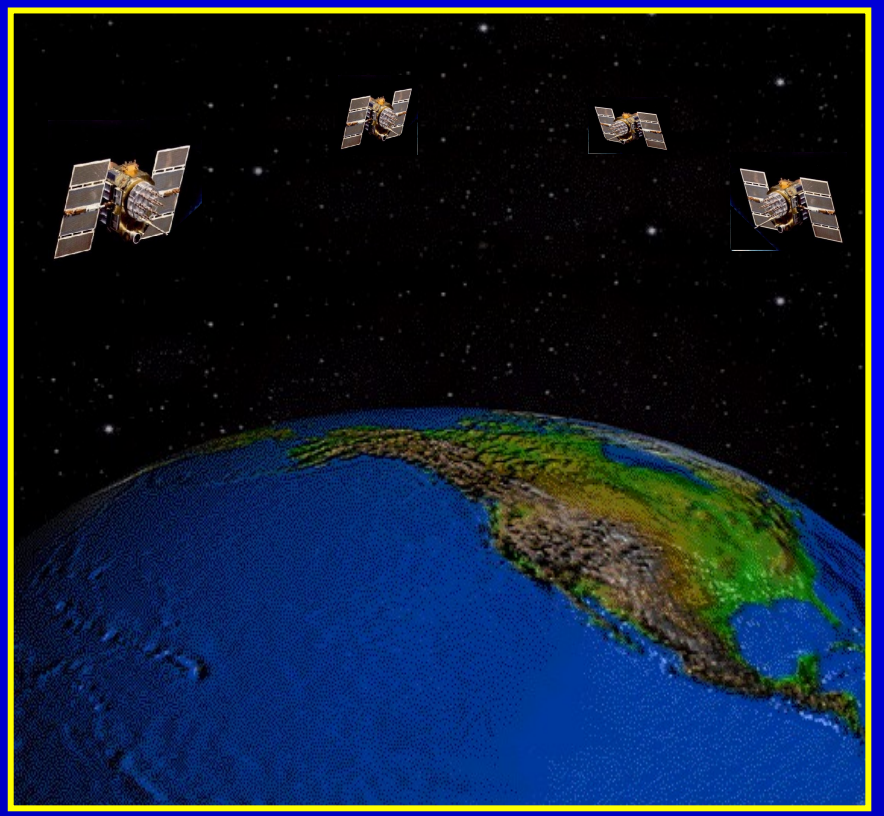
Hook-112

- **Hook-112 Survival Radio System provides:**
  - **Voice, beacon and a distance measuring equipment transponder, all of which currently exist with the AN/PRC-112 Survival Radio**
  - **PLUS GPS Standard Positioning Service, giving location coordinates using latitude and longitude or local area military grids**
  - **Custom or ‘canned’ messages that can be added to location and ID**
  - **LPI/LPD burst radio transmission capability**

Combat Survivor/Evader Locator (CSEL)

Overview

- Missions
- System Overview
- Limitations
- Enhancements
- Modernization
- Tactical GPS
- SUMMARY



Summary

- Comprehend how satellite navigation systems are employed in support of Air Force and Joint military operations
  - Comprehend the capabilities and limitations of satellite navigation systems
- Comprehend how Navigation Warfare concepts enhance GPS employment
- Comprehend how GPS contributes to military operations
- Value the integration of satellite navigation systems with military operations

Global Positioning System Introduction and Military Use

Business of Space
5 Dec 2001

Capt David Shultz
Space Operations Scho